SYNOPSIS

The lubricants that are applied during metal cutting acts on the interface between the tool and the nascent surfaces generated by the cutting process. Dispersions of oil in water made using suitable emulsifier(s) are used as metal cutting lubricants. The efficiency of the emulsion in rendering a low friction layer on the freshly cut surface will depend on the composition of the emulsion and on the speed, load and temperature characteristics in the tribological system.

A unique tribometer which can perform friction testing on freshly cut surfaces has been designed and built for the experimental investigation. In this experimental facility experiments are conducted by performing cutting operation inside a pool of the lubricant and friction force is measured in-situ. Experiments at different loads and speeds were performed. The surfaces were subsequently subjected to spectroscopic analysis using X-ray Photoelectron spectroscopy and Fourier Transform Infrared Spectroscopy (FTIR).

Lubricity of the base oils on nascent and preformed (oxidized) surfaces are compared by performing friction tests on surfaces which are cut and friction tested without exposing them to the environment, and on surfaces which were cut and exposed to the environment. While the freshly cut surfaces were seen to be sensitive to the structure of the base oil, the oxidized surfaces did not differentiate between the oil structures. Amongst the three base oils tested, aromatic oil was found to exhibit the least friction. This is attributed to tendency of the aromatic chains to react with the surface and form a film, due to the formation of radical anion-metal cation complexes. Results from spectroscopic investigations are presented to substantiate these arguments.

The thesis then explores the differences in the tribological behavior promoted by an emulsion between, when it acts on a cut surface and is slid just once, and when it acts on a cut surface slid repeatedly. Due to repeated sliding, friction was found to decrease with sliding time (distance), and the transition from a freshly formed surface to a repeatedly slid one was found to follow a smooth transition. The improvement in lubricity is attributed to the formation of carboxylate type structures (C=O) which get generated due to the tribological action under repeated sliding conditions in the presence of water. Under repeated sliding conditions, the friction as a function of emulsifier concentration is found to exhibit a minimum at a value which is much below the critical micellar concentration of the emulsifier (CMC). However, the variation under continuous cutting followed a different pattern, with the friction undergoing a sharp decrease close to the CMC.

The effect of speed on the tribological performance was investigated and friction was found to increase dramatically beyond a critical speed which is marked as the onset of starvation. The characteristic time required for a film to develop on a newly created surface, together with the contact pressure conditions dictated by the load and speed dictates starvation. The films formed at speeds corresponding to starvation conditions was found to have a significantly different chemical structure from that corresponding to a speed less than the starvation speed.. The effect of temperature was found to affect the lubricity adversely. At elevated temperature, the nature of the film was found to change to that to starved condition, even at a speed which does not register starvation when operating at a lower temperature.

The effect of solubility of the emulsifier on the friction characteristics were explored by using emulsifiers of varying hydrophilic-lypophilic values (HLB). Lower HLB emulsifiers were found to exhibit lesser friction, than those corresponding to high

HLB value. The variation in lubricity is examined in the light of the morphology of the micellar structures which evolve using these emulsifiers.

The main conclusions of the thesis are:

1. Evaluation of lubricity of metal cutting fluids warrants a testing strategy which tests their lubricity on freshly cut surfaces.

2. The formation of carboxylate structures aids lubricity while using an emulsion; emulsions which can result in the formation of such structures exhibit better lubricity under cutting conditions.

3. Tribofilms which show characteristic peaks related to chemisorbed oxygen is found to exhibit good lubricity under the test conditions.

4. Emulsifiers which form lamellar micellar structures which aid easy shear give better lubricity in cutting than those which yield spherical micelles.